Physiology of Flowering

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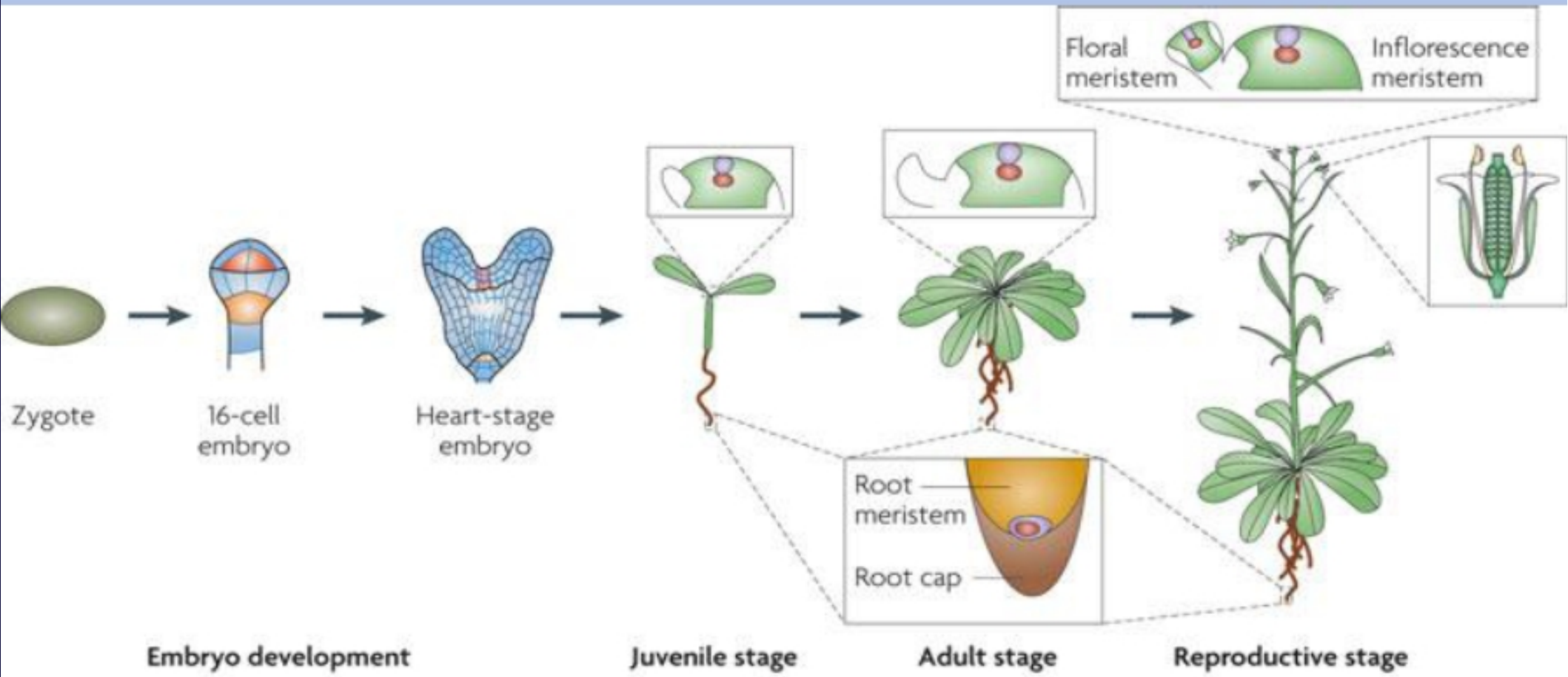
- How do plants keep track of the seasons of the year and the time of day?

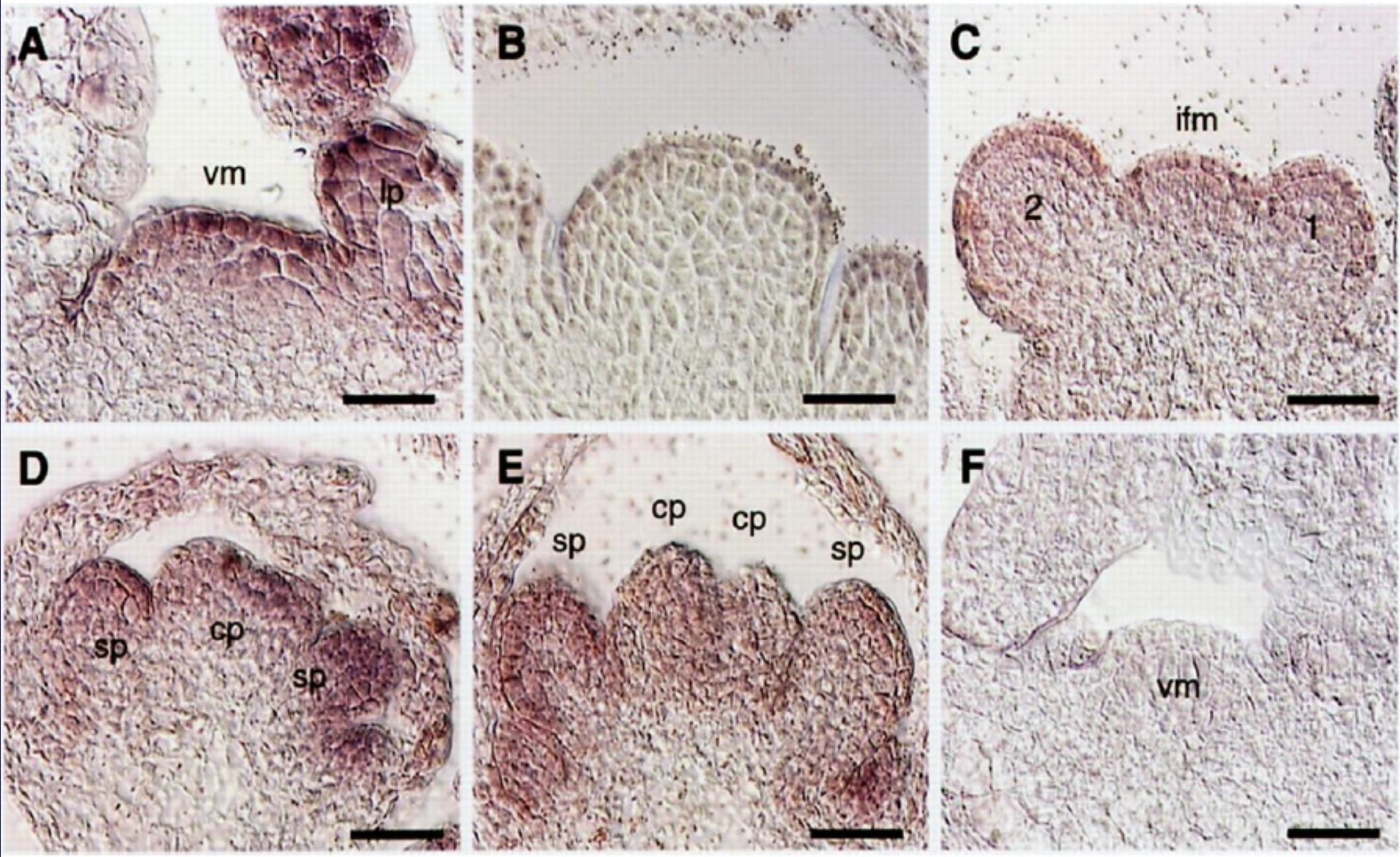
- Which environmental signals control flowering, and how are those signals perceived?

- How are environmental signals transduced to bring about the developmental changes associated with flowering?

juvenile vegetative phase
adult vegetative phase
adult reproductive phase
flowering



Nature Reviews | Genetics


A
vm
lp
B
C
ifm
2
1
D
sp
cp
sp
E
sp
cp
cp
sp
F
vm

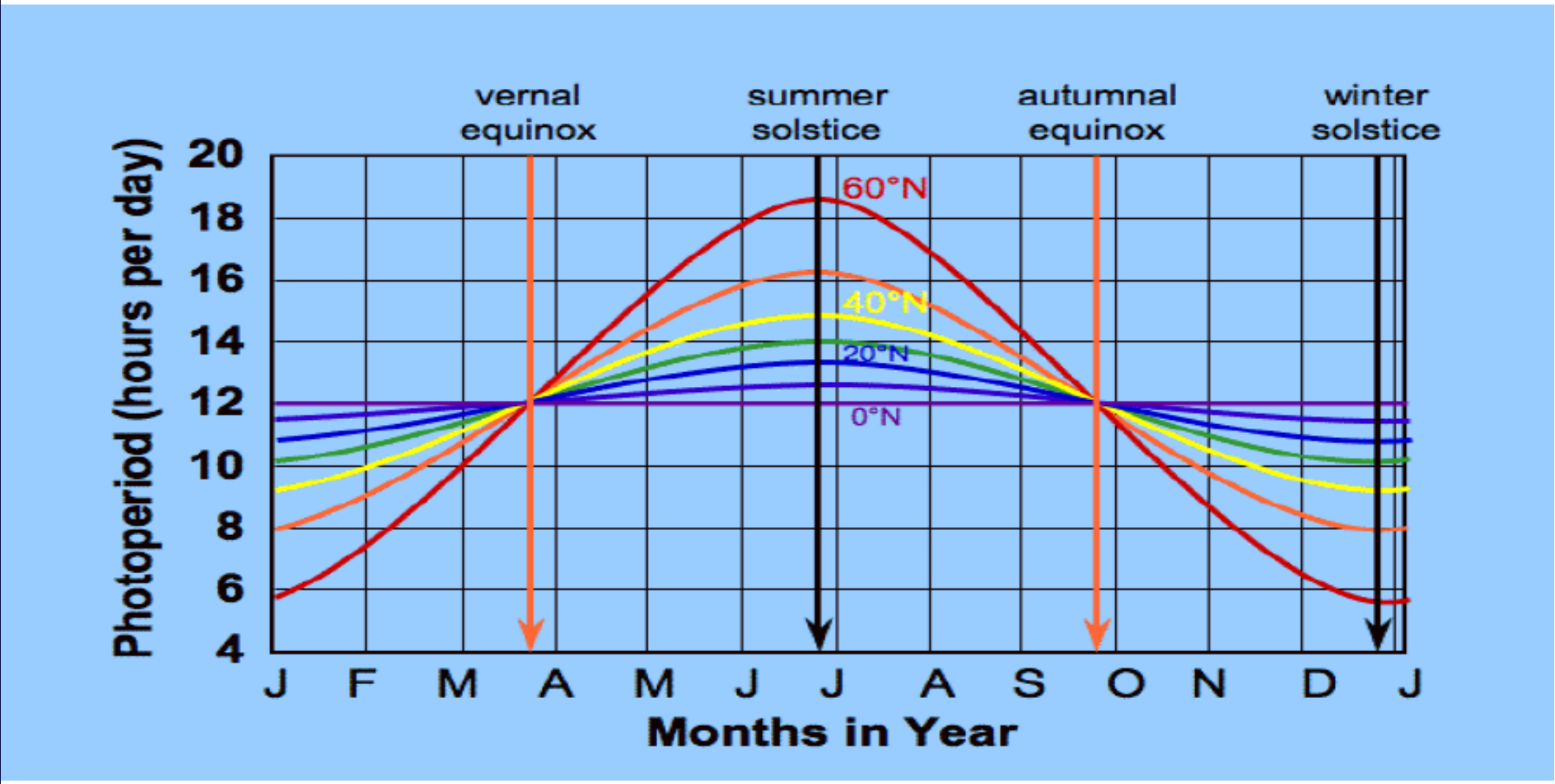
Ripeness to Flower

- size (*more important than age*)
- age (ex. bamboo);
- leaf number;
- growth conditions (conditions that favor growth promote the transition to adult phase; poor conditions, such as water stress, lack of light, low temp, prolong the juvenile phase)

Adult Vegetative-to-Reproductive Transition

Juvenile vegetative phase → transition factors (i.e., size, age) → induce hormonal or other changes → adult vegetative phase (competent) → environmental signal (i.e., photoperiod, temperature) → adult reproductive phase (determined) → flowering expressed

Photoperiod



The photoperiod required to induce flowering is referred to as the *critical day length*

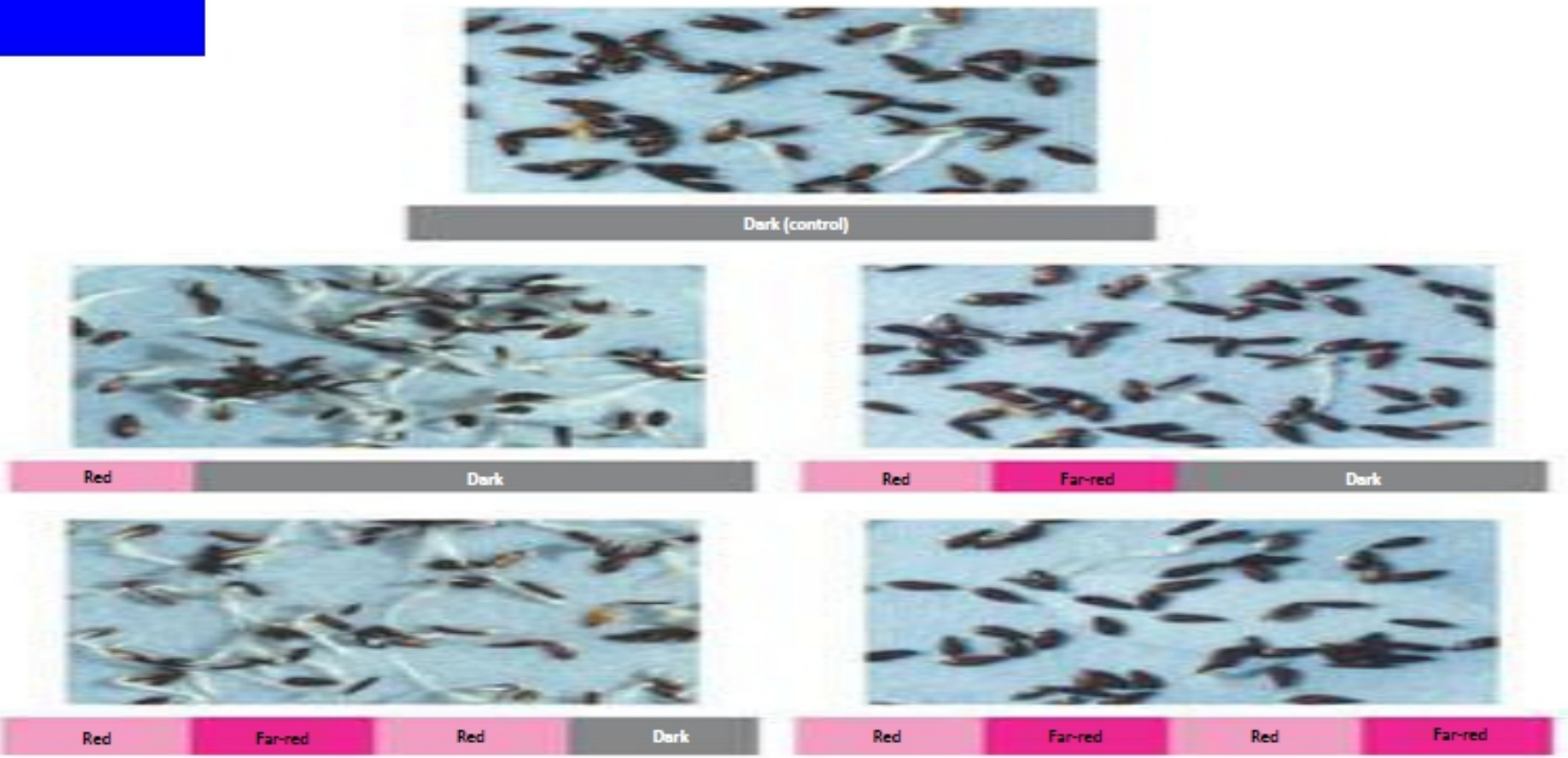
A short day plant is one that flowers on photoperiods shorter than the critical day length

Long day plants, on the other hand, are induced to flower on photoperiods longer than critical day length.

EXPERIMENT

During the 1930s, USDA scientists briefly exposed batches of lettuce seeds to red light or far-red light to test the effects on germination. After the light exposure, the seeds were placed in the dark, and the results were compared with control seeds that were not exposed to light.

RESULTS



CONCLUSION

Red light stimulated germination, and far-red light inhibited germination. The final exposure was the determining factor. The effects of red and far-red light were reversible.

- A phytochrome
  - Is the photoreceptor responsible for the opposing effects of red and far-red light

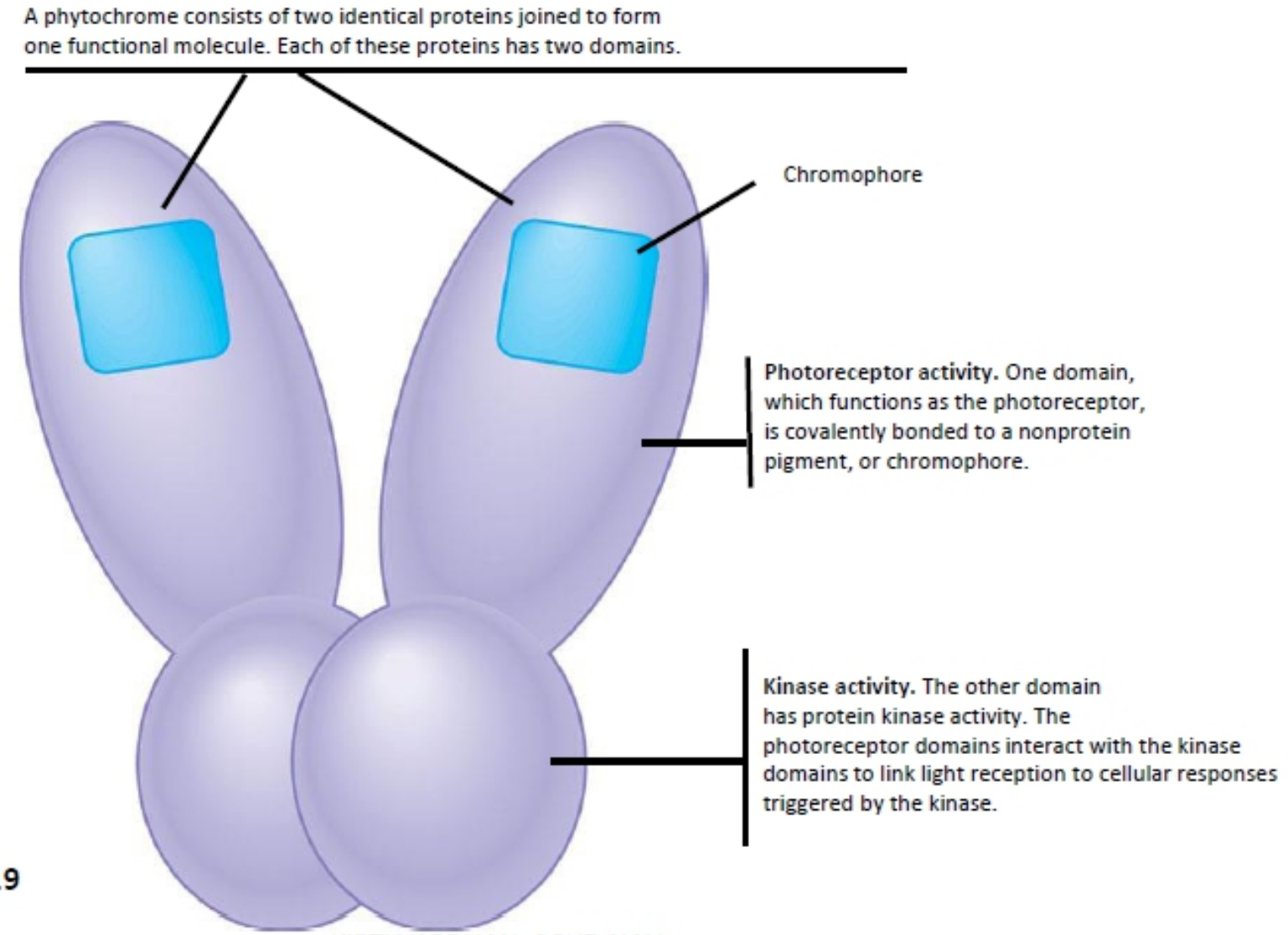


Figure 39.19

- Phytochromes exist in two photoreversible states
  - With conversion of P_r to P_{fr} triggering many developmental responses

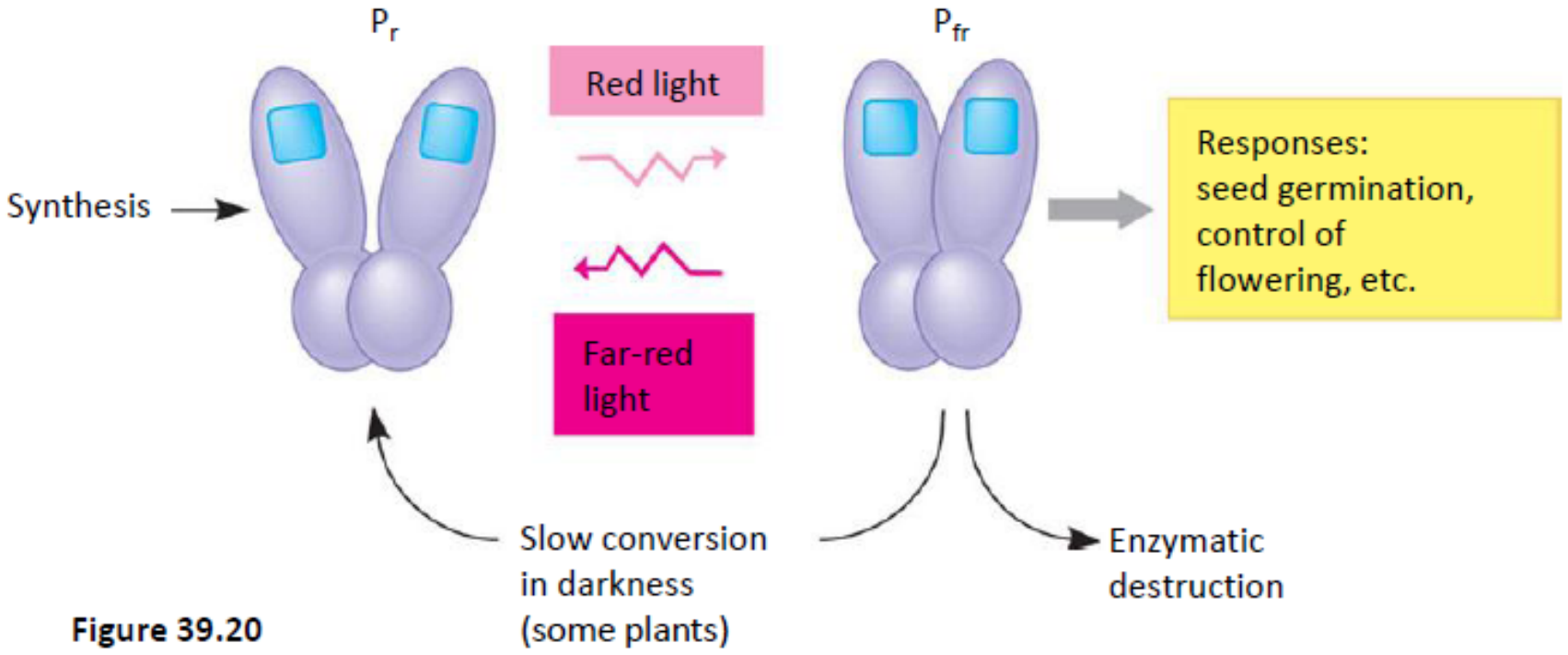
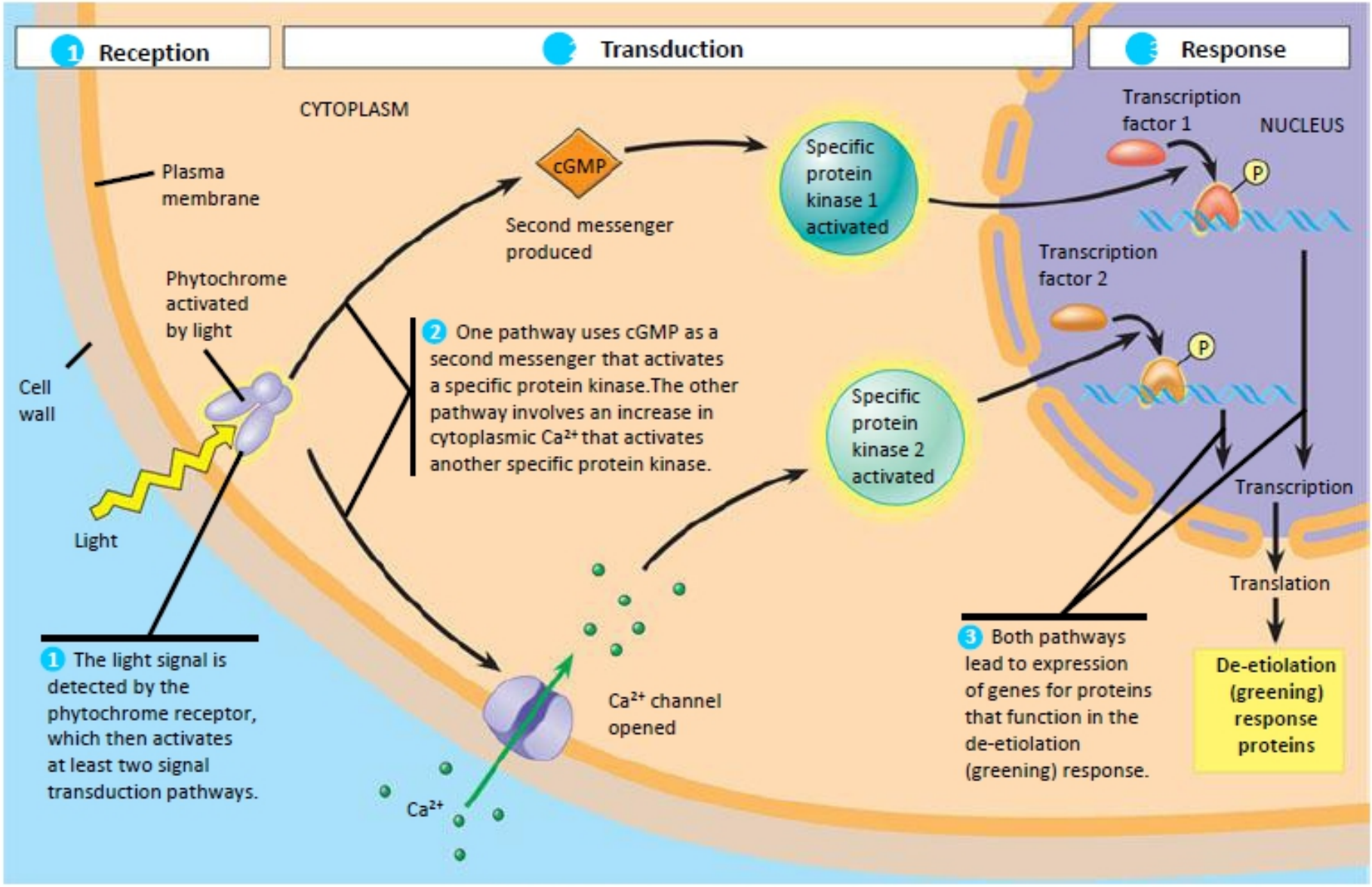


Figure 39.20

- An example of signal transduction in plants



Phytochromes and Shade Avoidance

- The phytochrome system
  - Also provides the plant with information about the quality of light
- In the "shade avoidance" response of a tree
  - The phytochrome ratio shifts in favor of P_r when a tree is shaded

Biological Clocks and Circadian Rhythms

- Many plant processes
  - Oscillate during the day

- Many legumes
  - Lower their leaves in the evening and raise them in the morning

Noon

Midnight

- Cyclical responses to environmental stimuli are called circadian rhythms
  - And are approximately 24 hours long
  - Can be entrained to exactly 24 hours by the day/night cycle

The Effect of Light on the Biological Clock

- Phytochrome conversion marks sunrise and sunset
  - Providing the biological clock with environmental cues

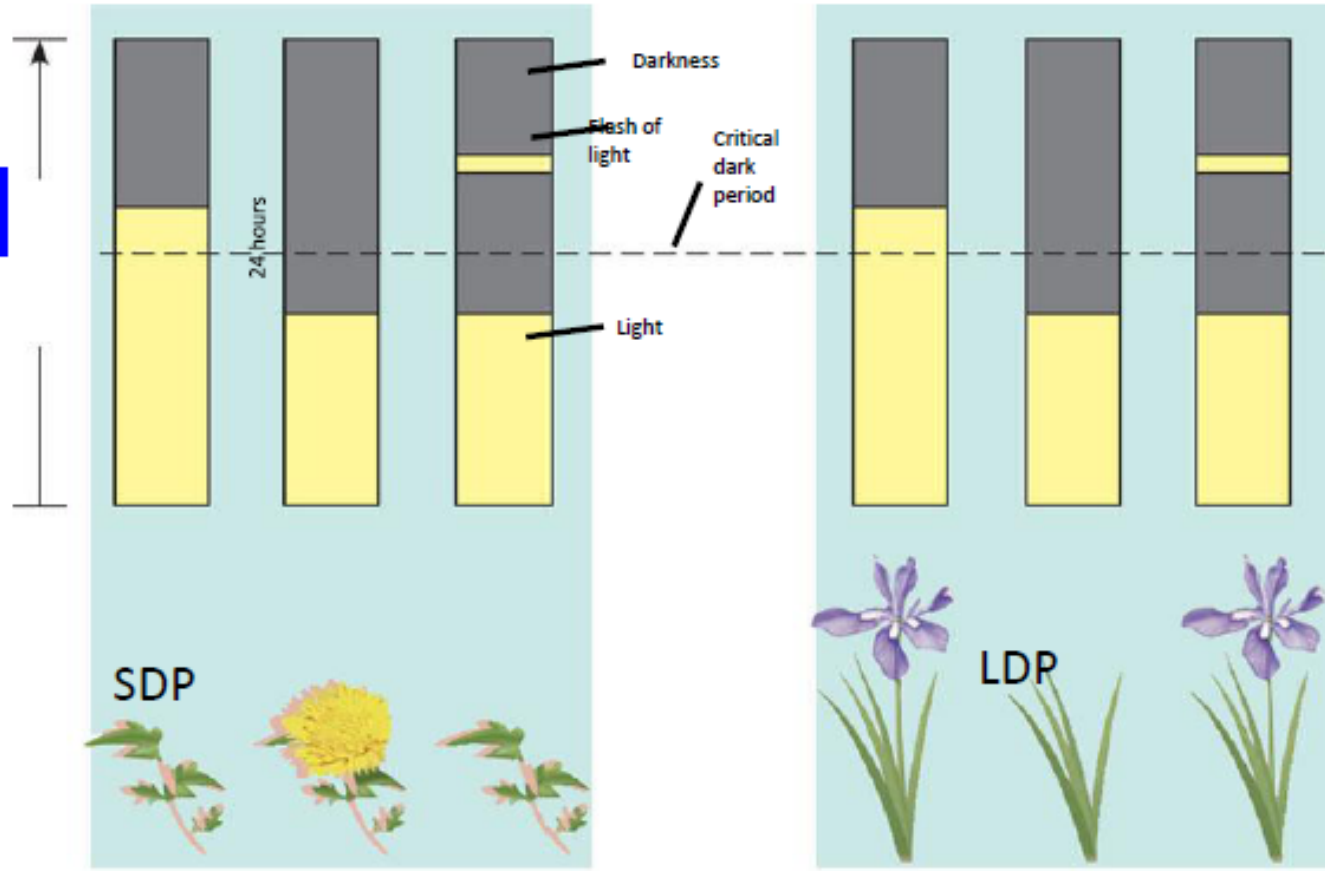
Critical Night Length

- In the 1940s, researchers discovered that flowering and other responses to photoperiod
  - Are actually controlled by night length, not day length

EXPERIMENT

During the 1940s, researchers conducted experiments in which periods of darkness were interrupted with brief exposure to light to test how the light and dark portions of a photoperiod affected flowering in "short-day" and "long-day" plants.

RESULTS



CONCLUSION

The experiments indicated that flowering of each species was determined by a critical period of *darkness* ("critical night length") for that species, *not* by a specific period of light. Therefore, "short-day" plants are more properly called "long-night" plants, and "long-day" plants are really "short-night" plants.

- Action spectra and photoreversibility experiments
  - Show that phytochrome is the pigment that receives red light, which can interrupt the nighttime portion of the photoperiod

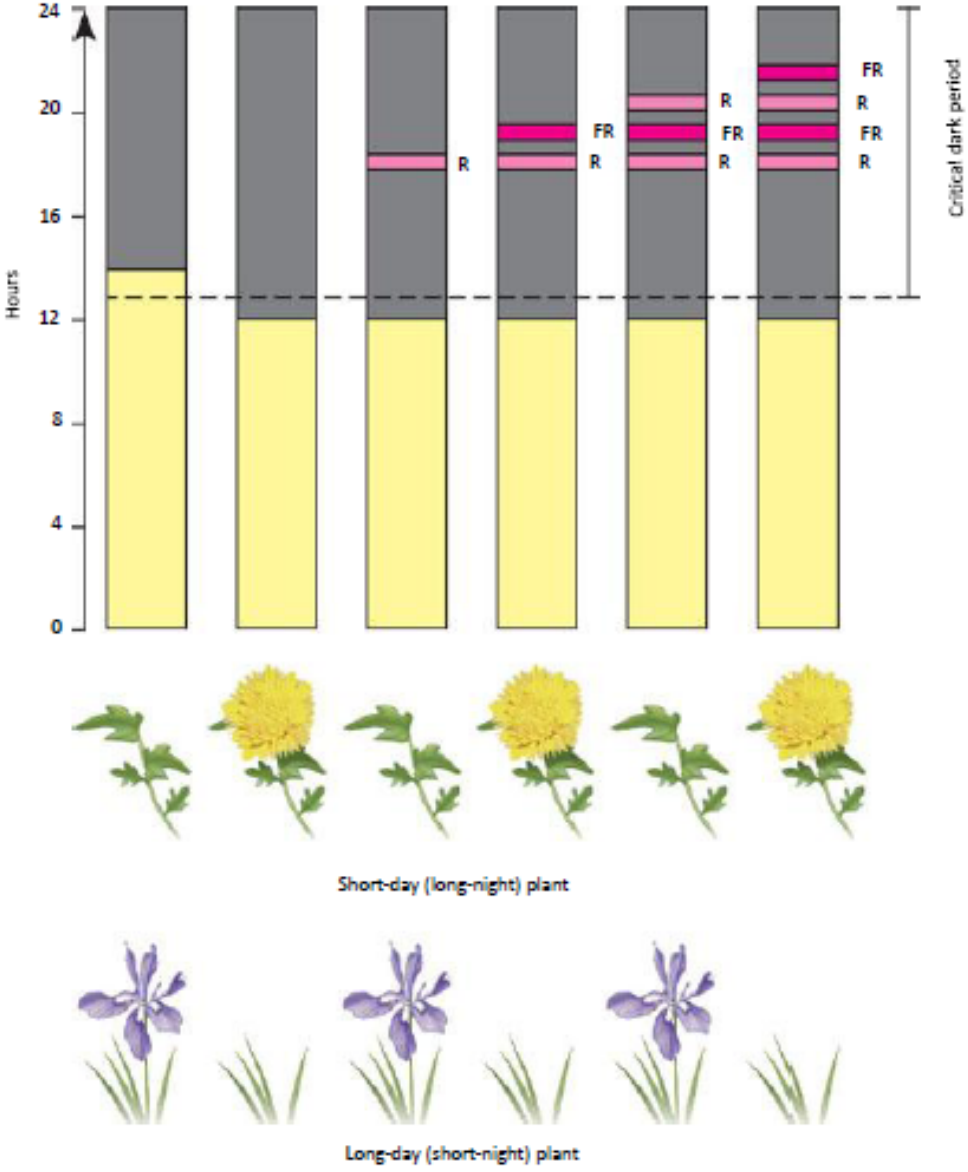
EXPERIMENT

RESULTS

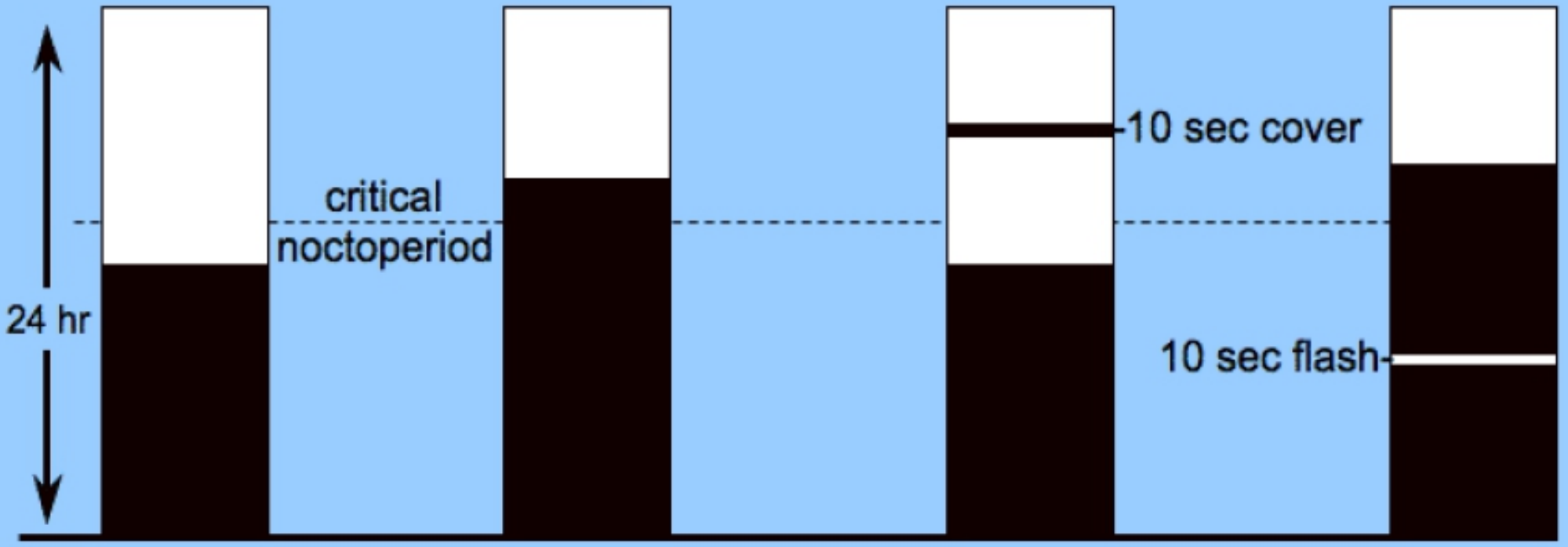
A unique characteristic of phytochrome is reversibility in response to red and far-red light. To test whether phytochrome is the pigment measuring interruption of dark periods, researchers observed how flashes of red light and far-red light affected flowering in "short-day" and "long-day" plants.

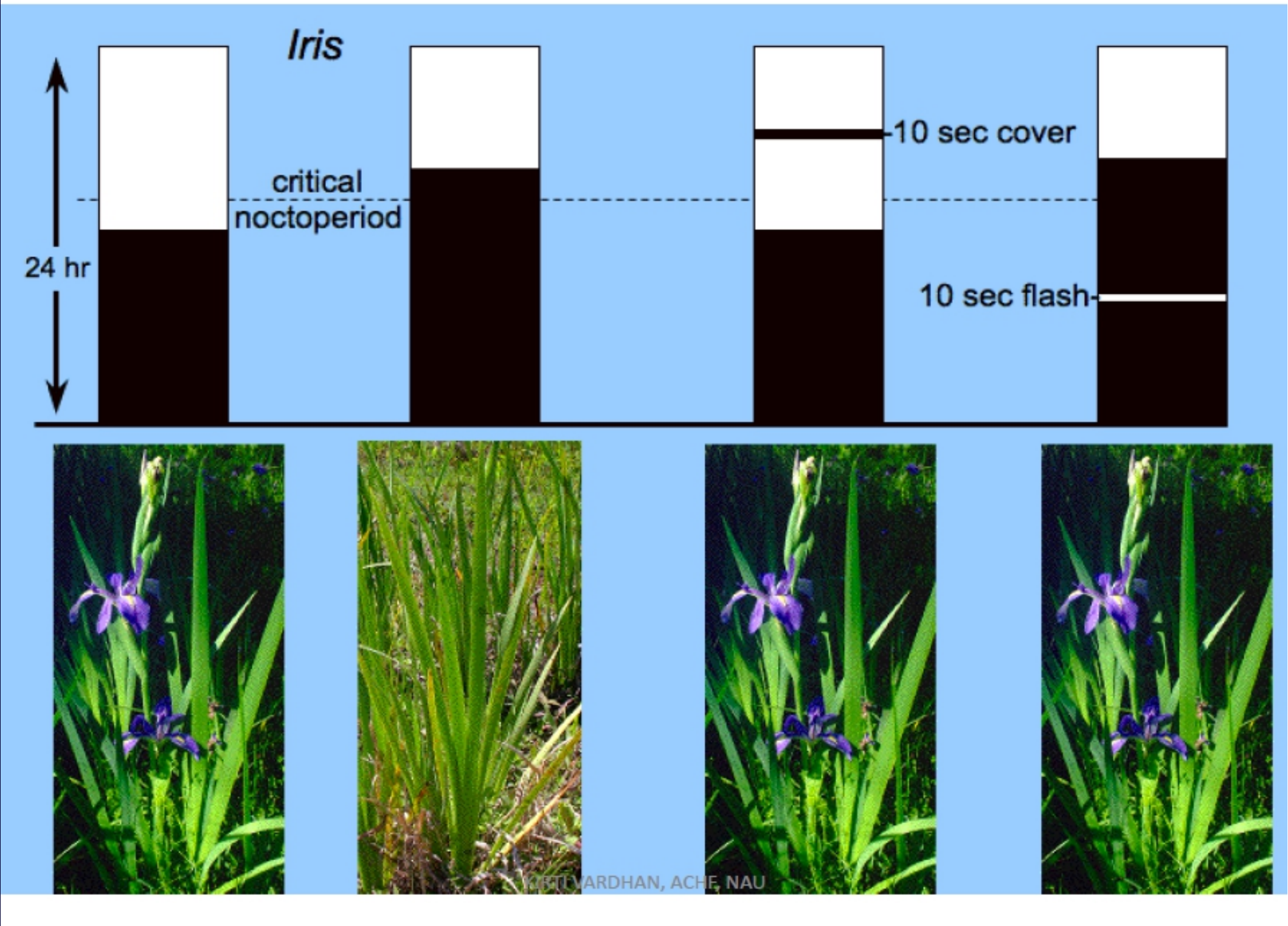
CONCLUSION

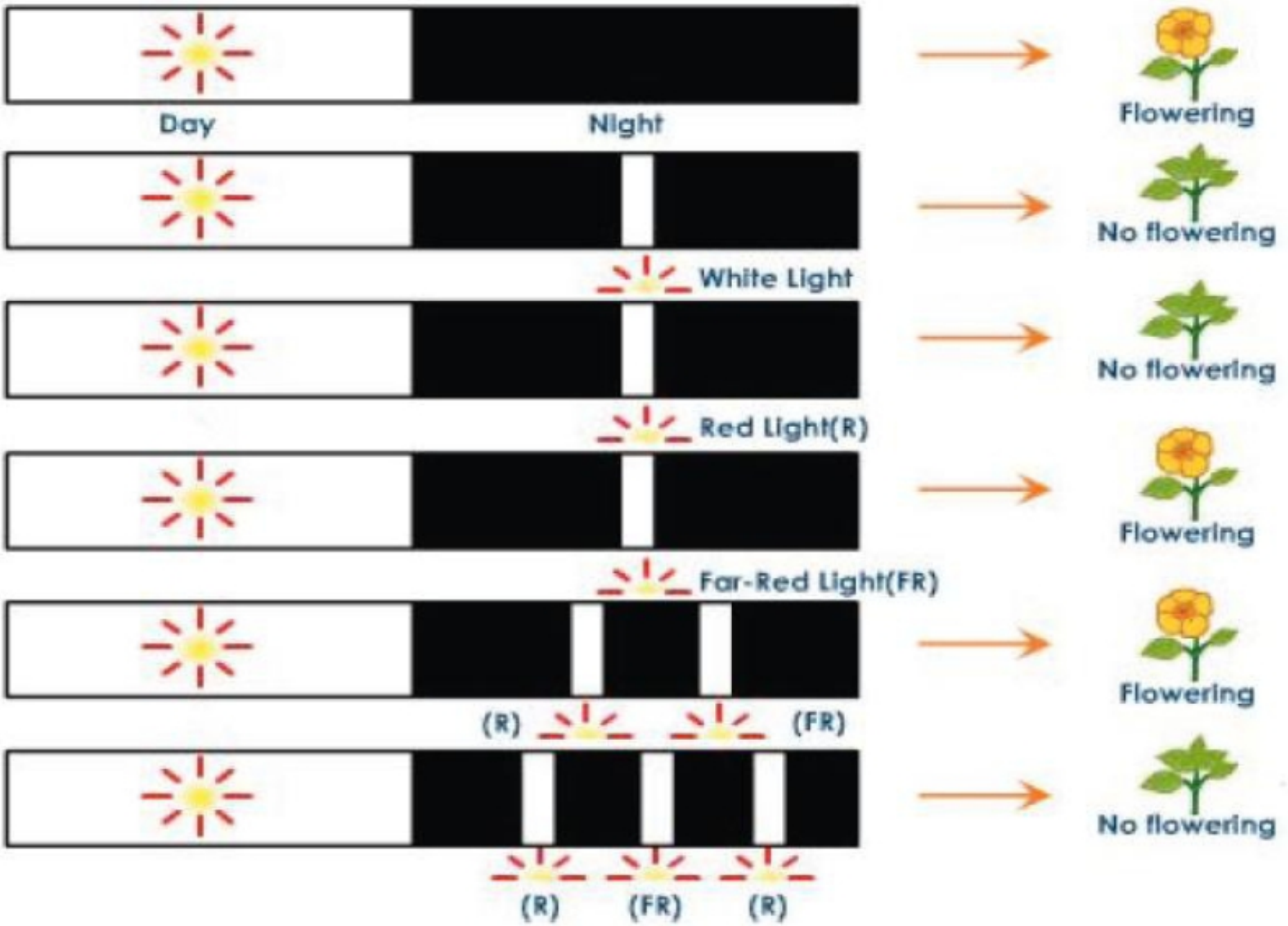
A flash of red light shortened the dark period. A subsequent flash of far-red light canceled the red light's effect. If a red flash followed a far-red flash, the effect of the far-red light was canceled. This reversibility indicated that it is phytochrome that measures the interruption of dark periods.



Poinsettia






Day
Night
Flowering
No flowering
White Light
No flowering
Red Light(R)
Flowering
Far-Red Light(FR)
Flowering
(R)
(FR)
No flowering
(R)
(FR)
(R)

P_R -- Form favours flowering in short day plants

Continuous dark → Accumulation of more P_R

↓

Flowering in SD plants

P_{FR} -- Form favours flowering in long day plants

Continuous Light → Accumulation of more P_{FR}

↓

Flowering in LD plants

Phytochrome Mediated Responses in Crop Plants

1. Seed germination

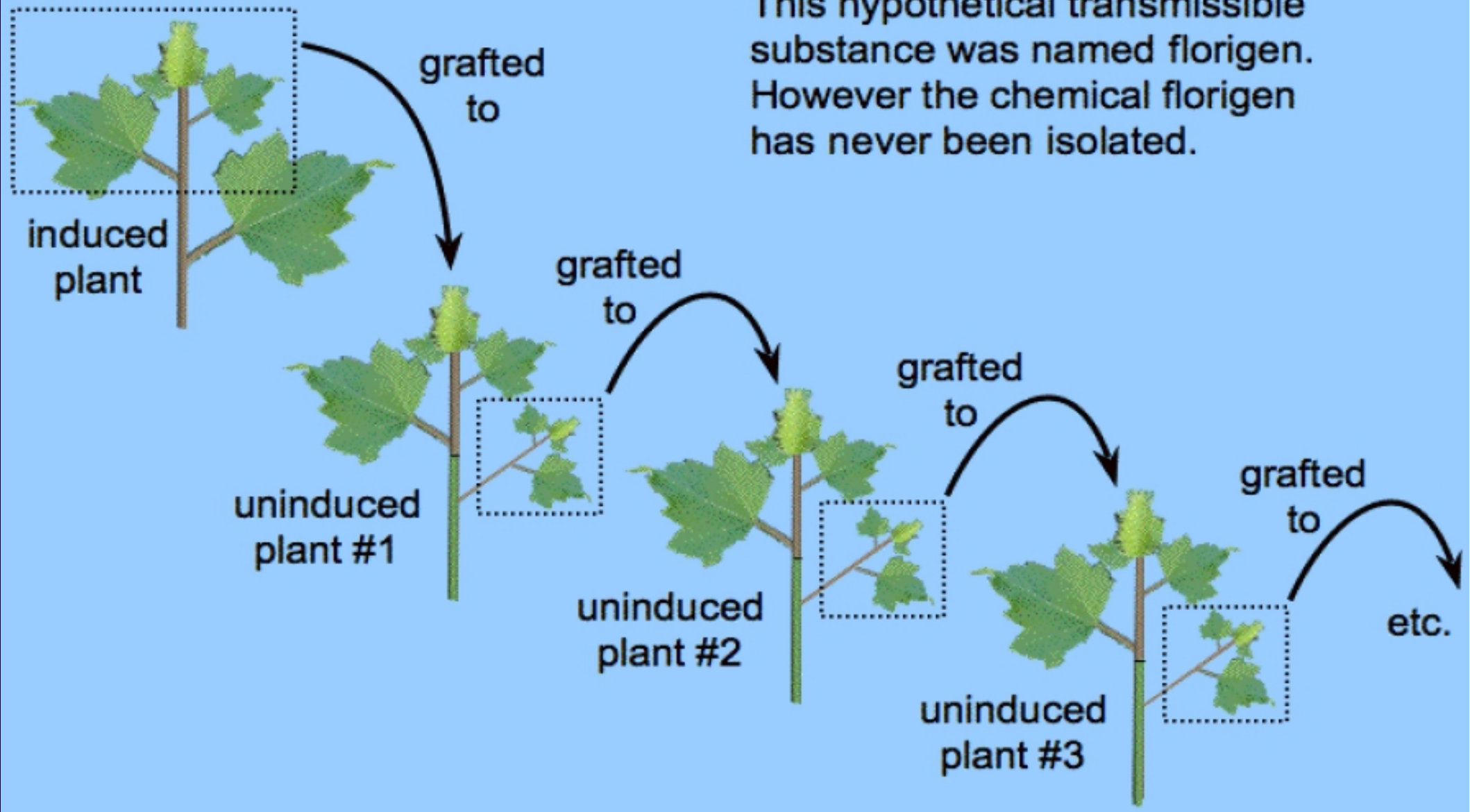
2. Flowering

3. Pollen germination

4. Chlorophyll synthesis

5. Enzyme activity

Induction signal can be transmitted through serial grafts in *Xanthium*



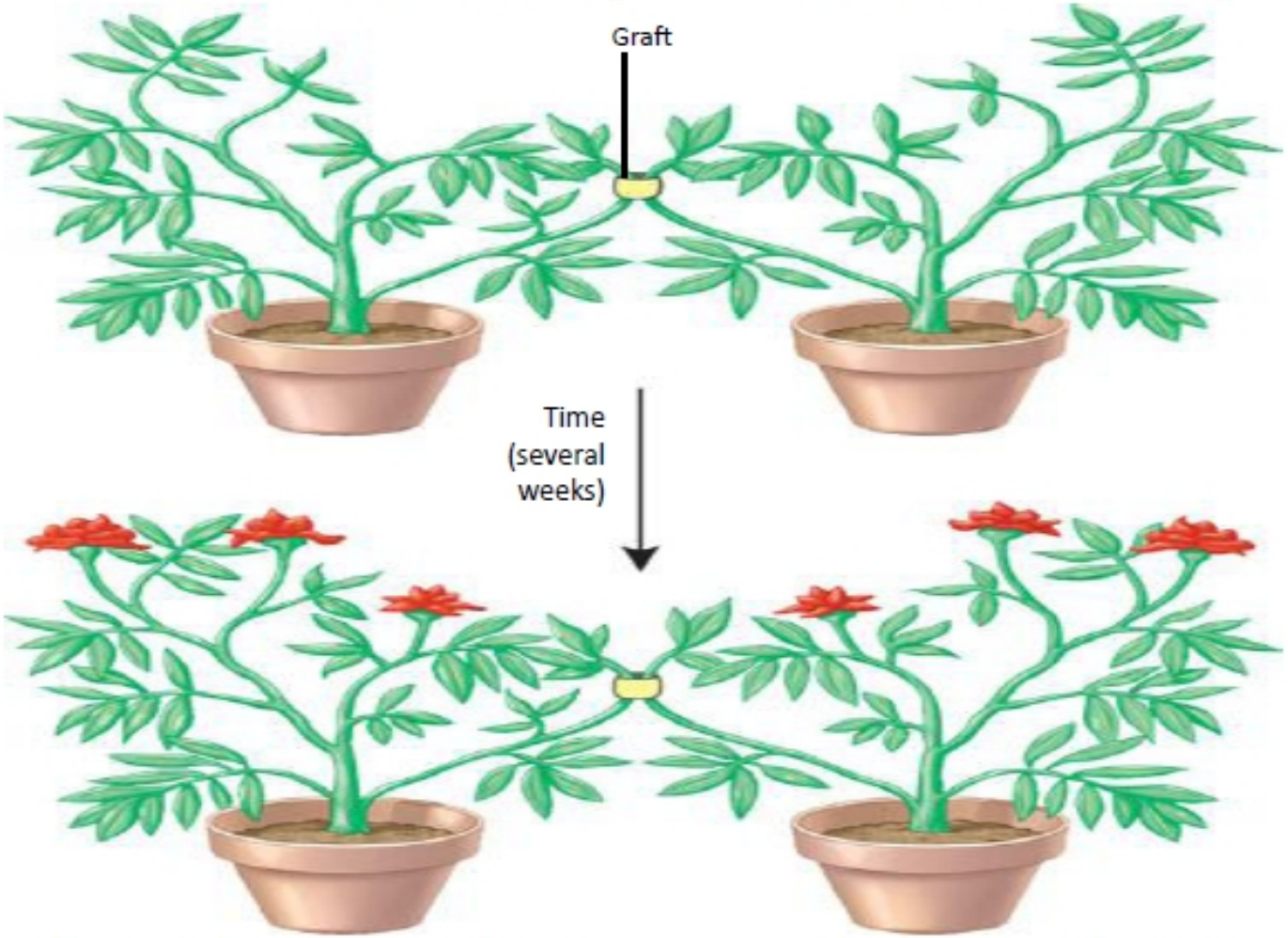
EXPERIMENT

To test whether there is a flowering hormone, researchers conducted an experiment in which a plant that had been induced to flower by photoperiod was grafted to a plant that had not been induced.

RESULTS

Plant subjected to photoperiod that does not induce flowering

Plant subjected to photoperiod that induces flowering



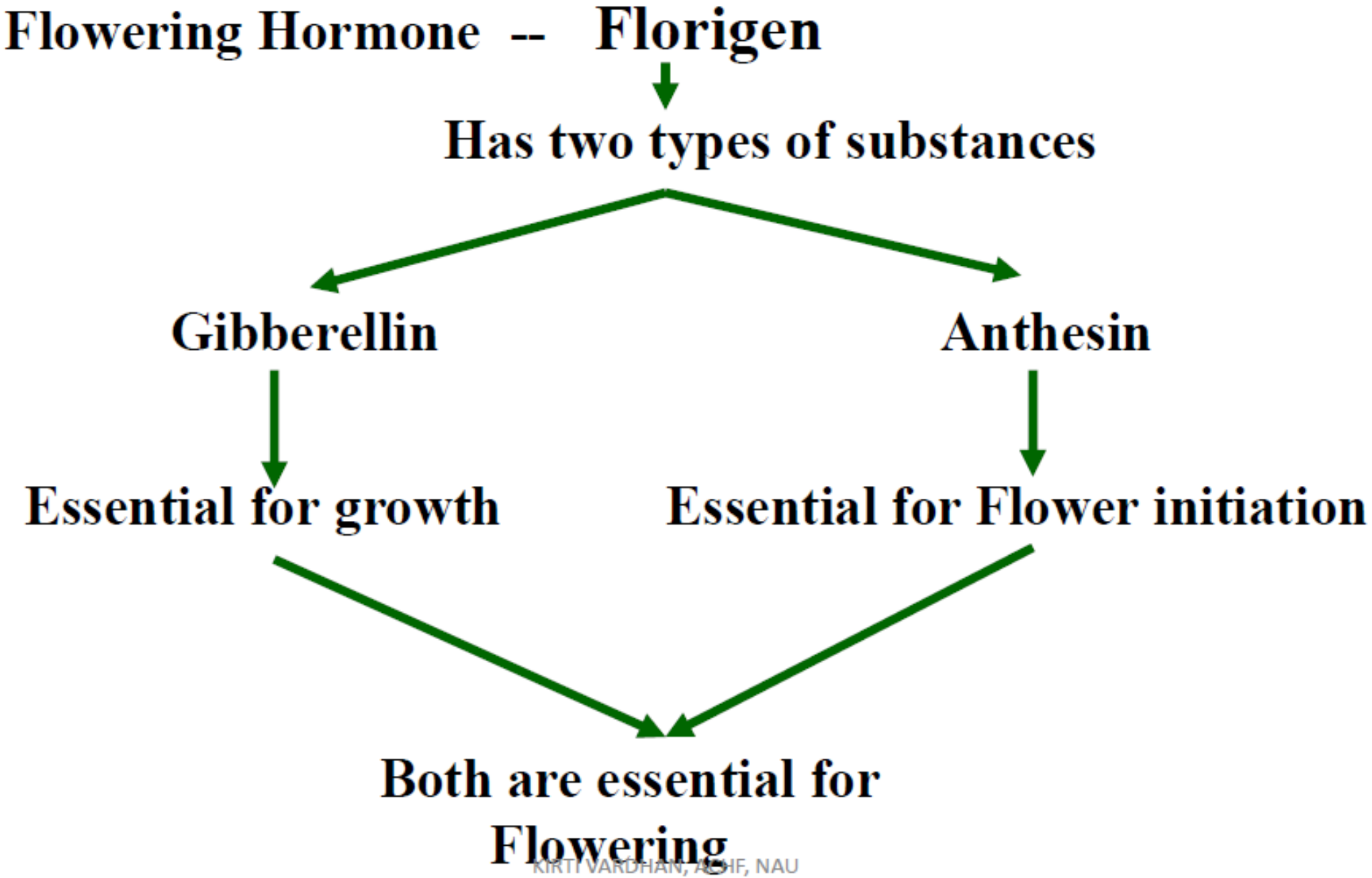
CONCLUSION

Both plants flowered, indicating the transmission of a flower-inducing substance. In some cases, the transmission worked even if one was a short-day plant and the other was a long-day plant.

A Flowering Hormone?

- The flowering signal, not yet chemically identified
  - Is called florigen, and it may be a hormone or a change in relative concentrations of multiple hormones

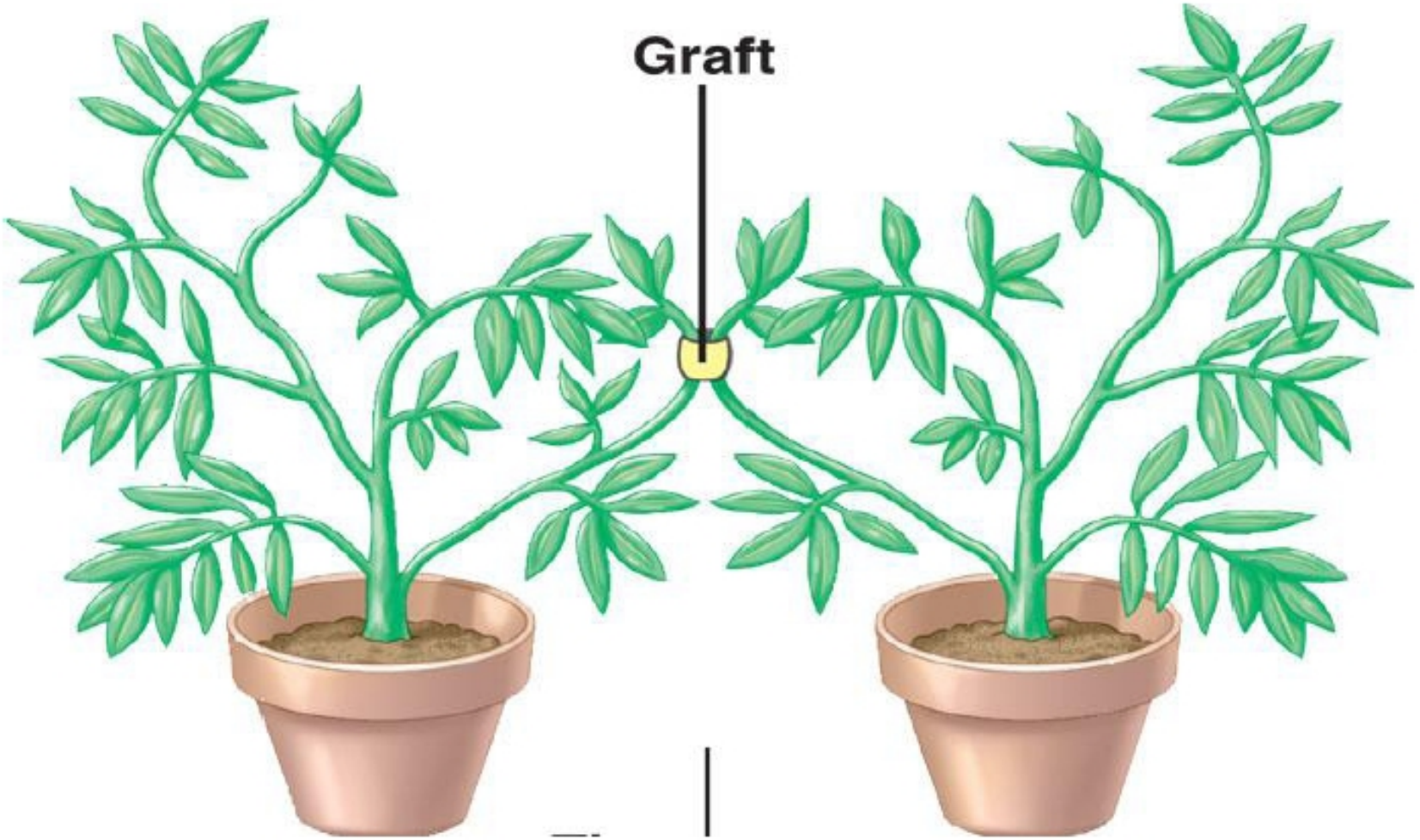
CHAILAKHYAN'S HYPOTHESIS

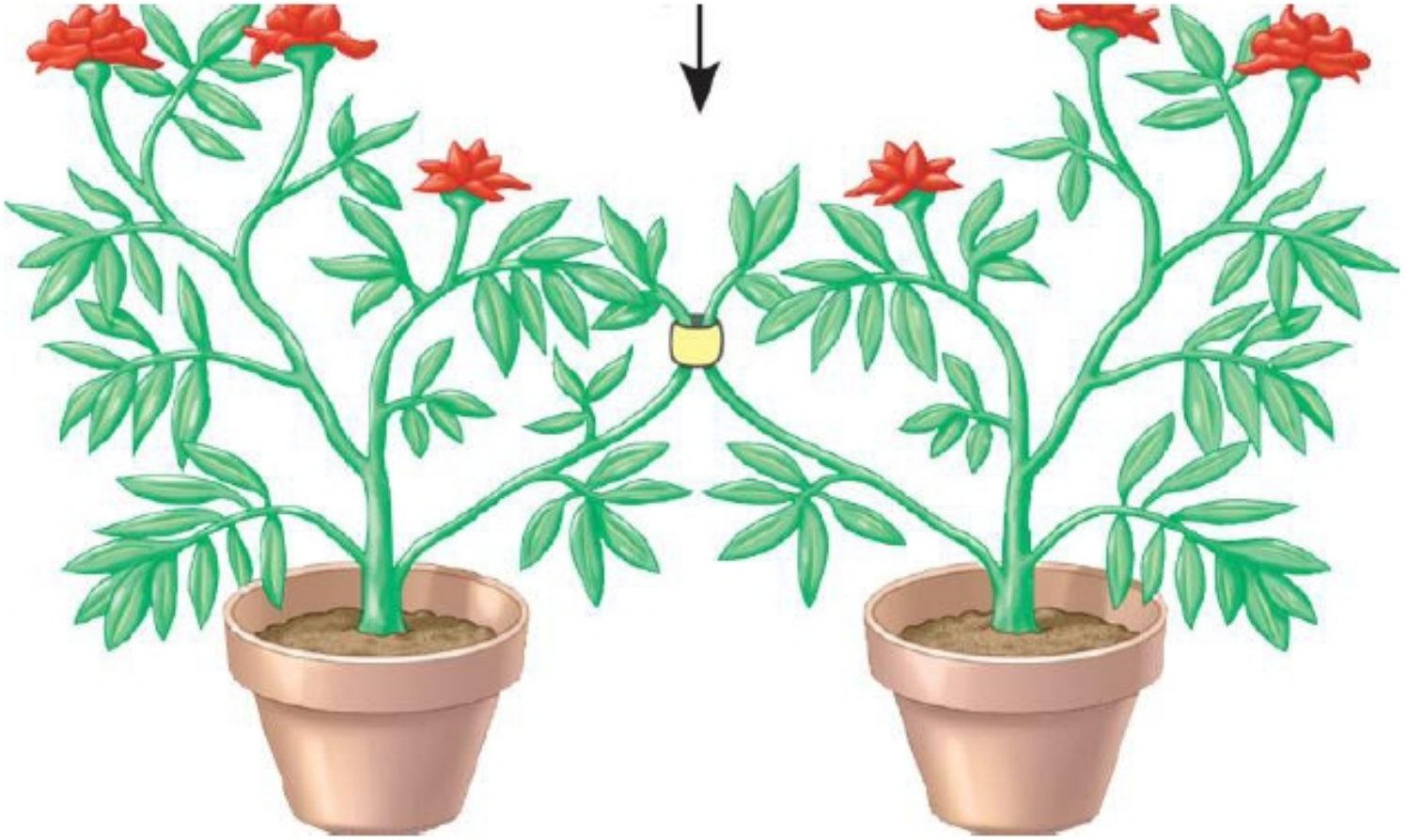


SHORT DAY PLANTS

SD condition

LD condition



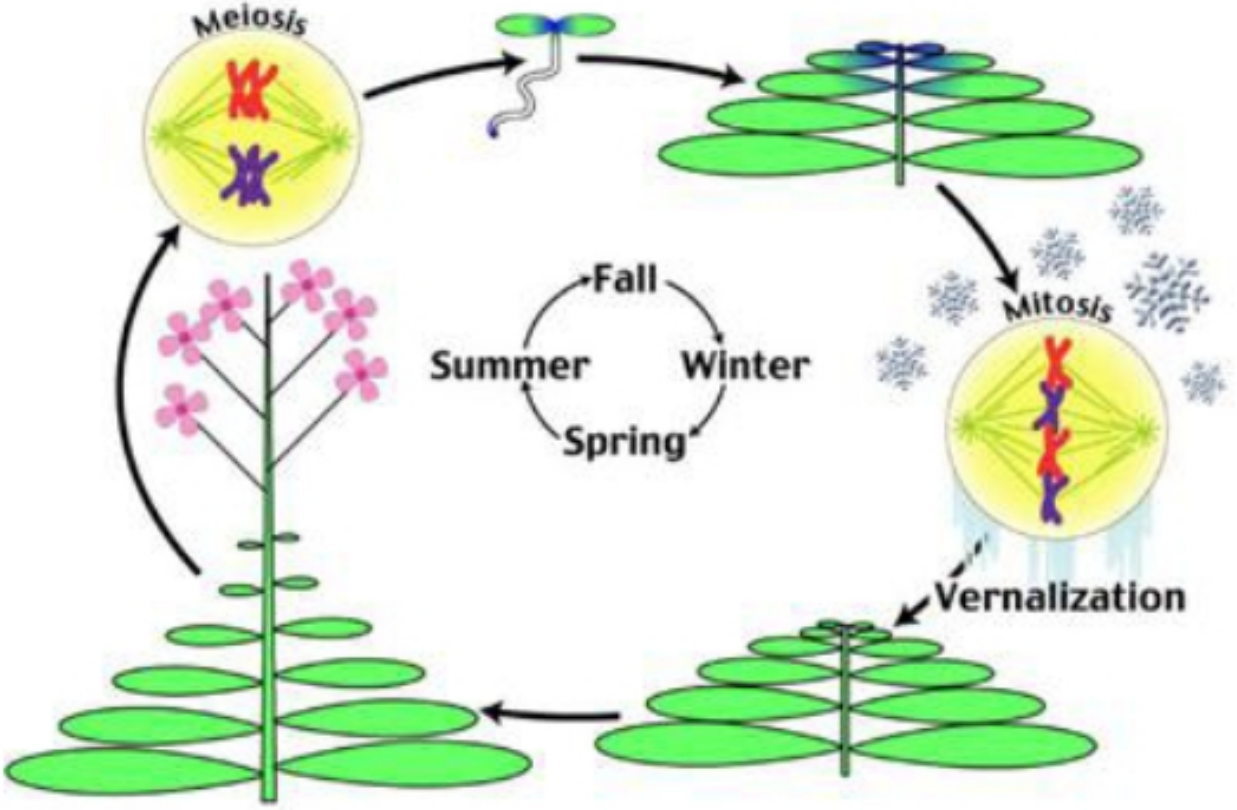


Florigen can be transmitted from one branch of the plant to other plant branch

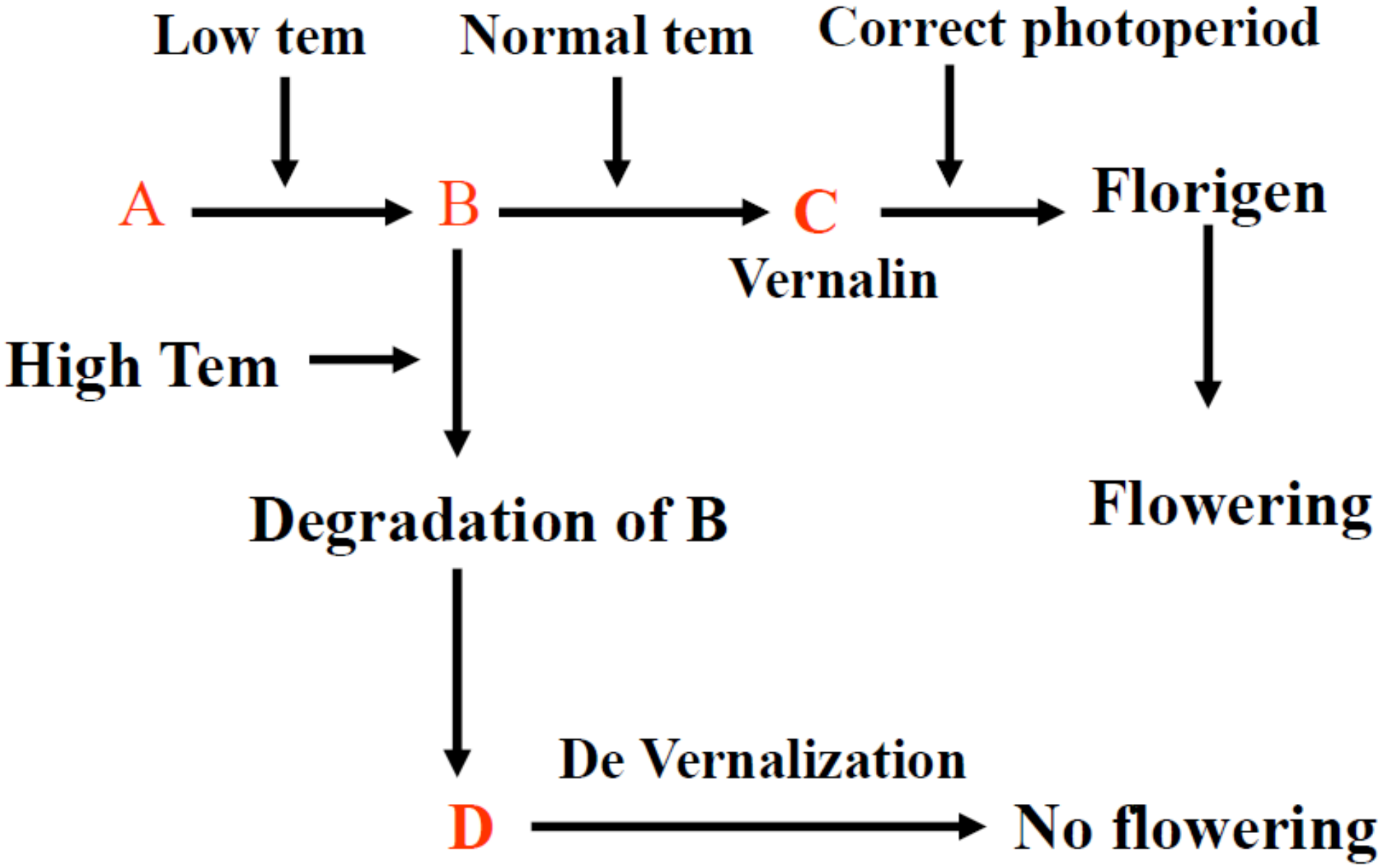
LD plants can be made to flowering under SD condition through Grafting

Vernalization:

Receptor
Signal



The biennial life cycle


Low tem
Normal tem
Correct photoperiod
A
B
C
Florigen
Vernalin
High Tem
Degradation of B
Flowering
De Vernalization
D
No flowering

Devernalization

The positive effect of the low temperature treatment on the vernalization of the plant can be counteracted by subsequent high temperature. This is called devernalization.

Or

Effect of vernalization can be removed by High temperature treatment. This reverse effect is called De vernalization

It occurs at more than 30°C

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Thank You